Synchrotron-Based Proton Driver R&D Plan

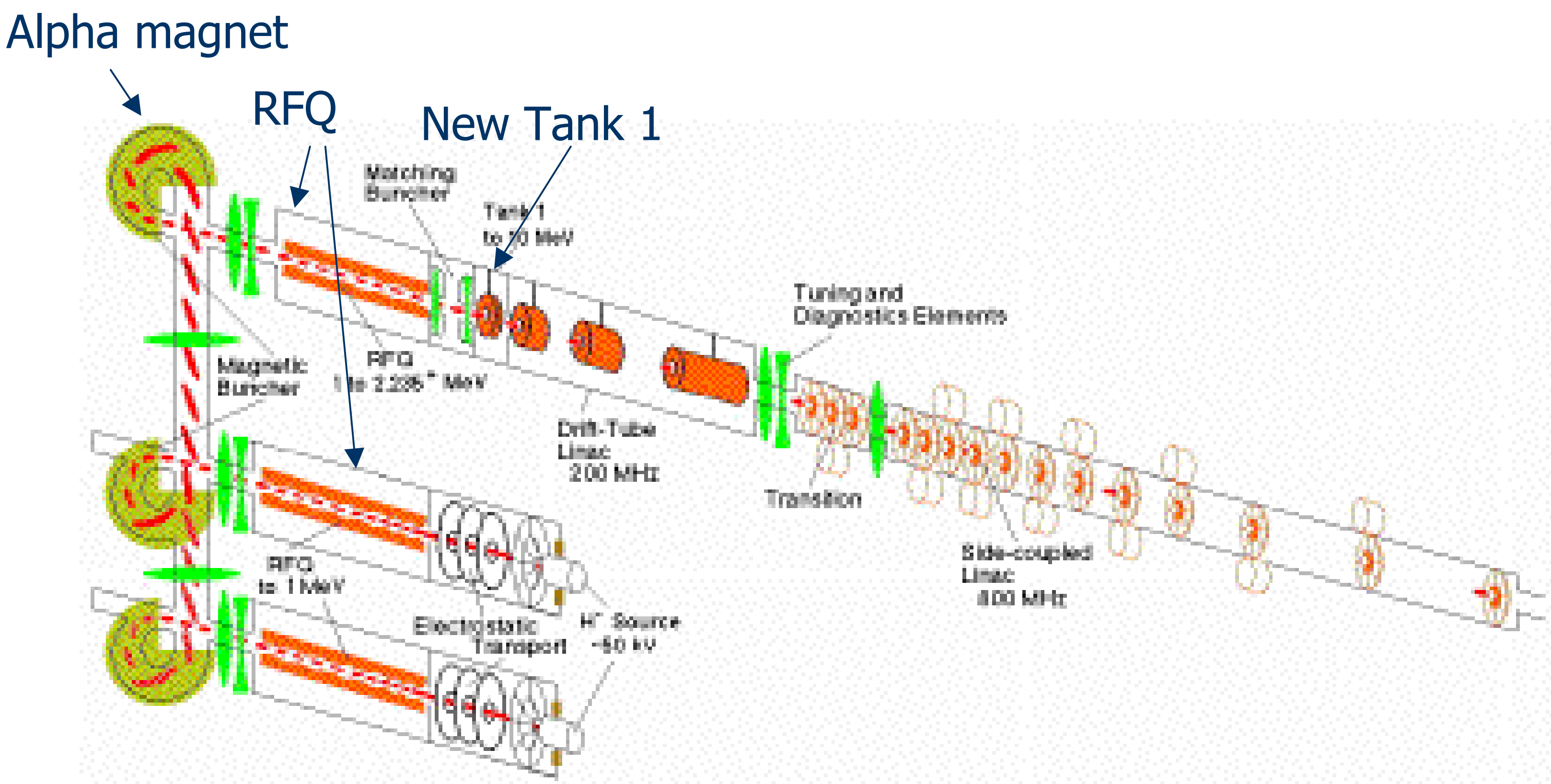
- Two parts:
  - Linac improvement
  - New 8 GeV synchrotron
- The linac part is more like a project. It is the “common denominator” of the two options (linear vs. circular) and can go ahead regardless which option would be chosen.
- Several items in the synchrotron part are coupled with the present Booster. They will help improve the Booster performance (an advantage of the synchrotron option). Sometimes even the cost can be absorbed by BD or collaborating institutions (e.g., RF cavity modification).

R&D List

- Linac improvement ("*common denominator" of the two options*)
  - New 200 MHz front end & Tank 1 (10 MeV) *or*
  - New 402 MHz low energy section (116 MeV)
  - New 805 MHz sc high energy section (313 - 500 MeV, replacing CCL station no. 6 and 7)
  - Laser chopping
- New 8 GeV Synchrotron
  - Dual harmonic power supply test
  - Magnet R&D and field measurement
  - AC sc magnet development
  - Beam pipe prototyping
  - Space charge study
  - Collimation system
  - Booster RF cavity modification

New 200 MHz Front End & Tank 1

(10 MeV)



New 402 MHz Low Energy Section
(116 MeV)

Appendix of Ch. 8 in TM-2169 (PD2 report) describes the design of this section: (E. McCrory and D. Young)

Appendix   402 MHz Low-Energy Linac Replacement

Although not necessary for PD2, it would be highly desirable to consider the replacement of the entire drift-tube section of the Linac as part of the project for upgrade of the low-energy portion of the Linac. In the PD1 [1] arguments were made for the replacement of the Cockcroft-Walton preaccelerators by the more modern and accepted Radio-Frequency Quadrupole (RFQ) accelerating structure. Also it was pointed out that a large degradation in the quality of the accelerated beam occurs in the first drift-tube accelerating cavity, up to 10 MeV, as a result of the inferior alignment of the quadrupoles and the poor fabrication techniques used when this cavity served as a prototype for the fabrication of the other eight cavities in the Linac. The 200 MHz drift-tube section of the Linac is now over 30 years old and increasing operational demands are continually being requested…

New 402 MHz Low Energy Section (cont…)

				DTL			CCL	
	RFQ	Tank 1	Tank 2	Tank 3	Tank 4	Match Section	Mod 1	Mod 2
MeV	0.035	3	13.4	32.9	51.6	70.3	70.3	93.3
MeV	3	13.4	32.9	51.6	70.3	70.3	93.3	116.5
MeV	2.965	10.4	19.5	18.7	18.7	0	23	23.2
mA	70	55	55	55	55	50	50	50
MHz	402.5	402.5	402.5	402.5	402.5	805	805	805
usec	90	90	90	90	90	90	90	90
usec	130	130	130	130	130	125	125	125
Hz	15	15	15	15	15	15	15	15
	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
MV/m		2.4 to 4.6	4.6	4.6	4.6	7.5 to 7.35	8	8
m		4.5	6	6.1	6.2	3.25	4.8	4.9
MW		1	1.75	2	2		5.4	5.4
MW		0.63	1.07	1.02	1.02		1.38	1.39
MW		2.5	3.8	4	4		8.5	8.5

New 402 MHz Low Energy Section (cont...)

The cost estimate of this 402 MHz low-energy system in 2002 dollars is as follows (in K$):

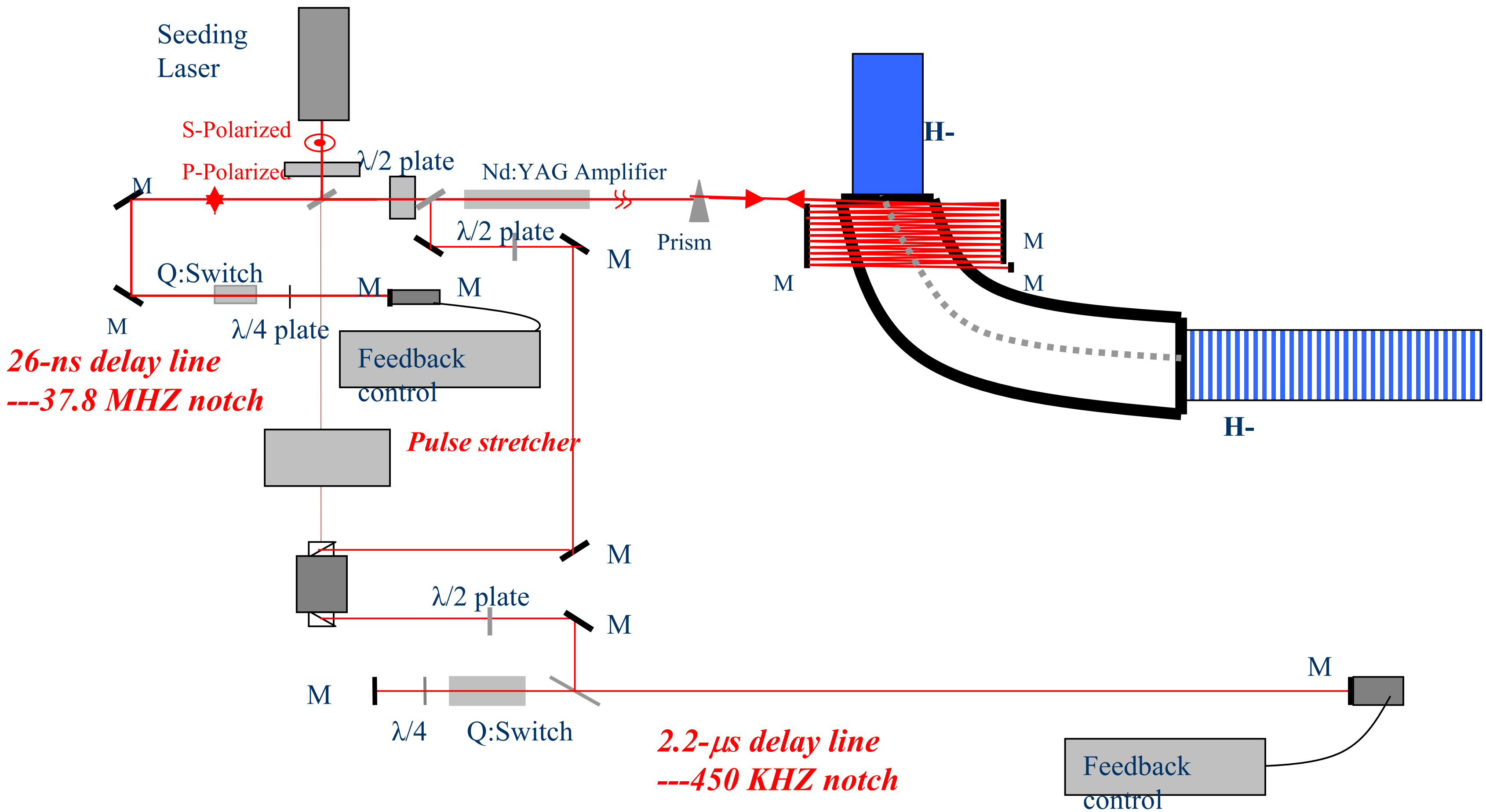
Components, including the RFQ, RGDTL, DTL, matching section, CCL, DTL rf systems, matching section rf systems, beam diagnostics, and the control systems	24,649
Installation and commissioning	2,500
Building modifications	500
TOTAL (K$)	27,649

New 805 MHz SC High Energy Section
(313 – 500 MeV)

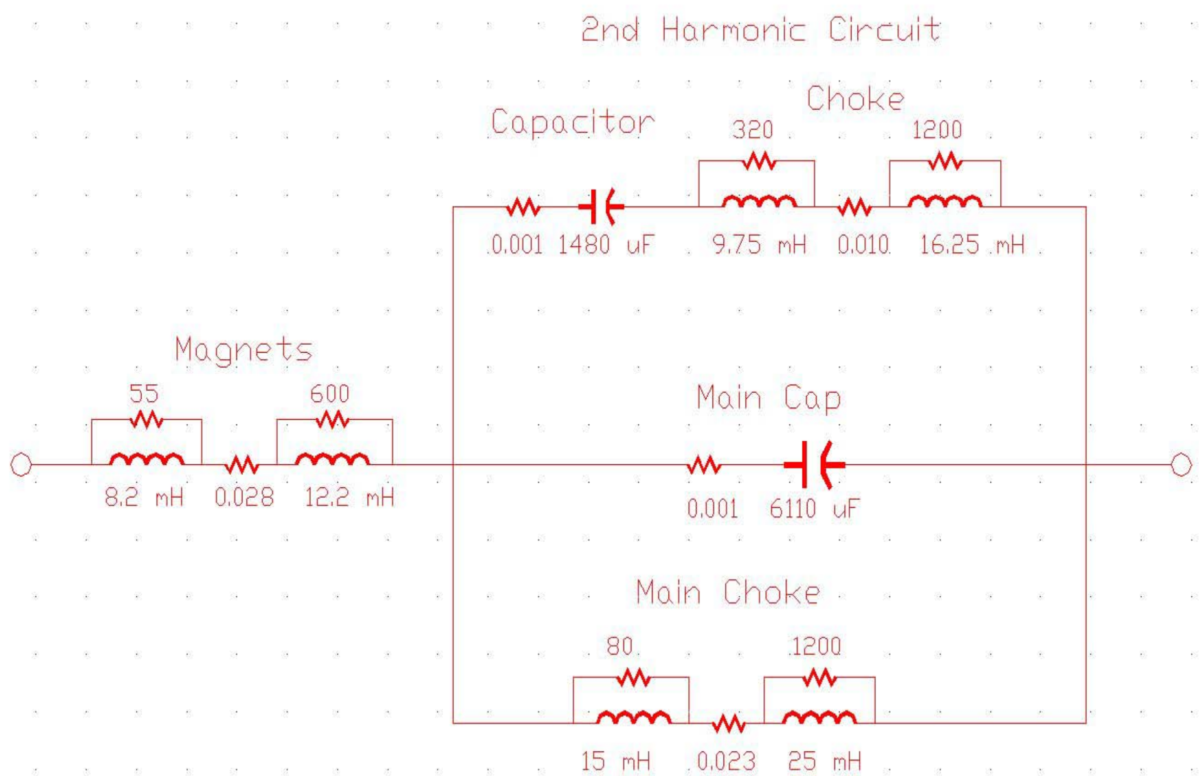
- Retain the existing CCL stations No. 1-5 for accelerating the beam to 313.6 MeV.
- Replace the last two CCL stations No. 6-7 by SNS-type β=0.81 sc cavity for an energy upgrade to 500 MeV.
- The requires a "real estate" gradient of 9.5 MV/m in a 19.5 m long space, which is feasible.
  - The peak field is 35 MV/m, already achieved by the SNS
  - The fill factor is 0.63, which will require some changes in the SNS design (using quadrupole doublet, replacing SNS input coupler by TESLA type)

Laser Chopping

(R. Tomlin and X. Yang)

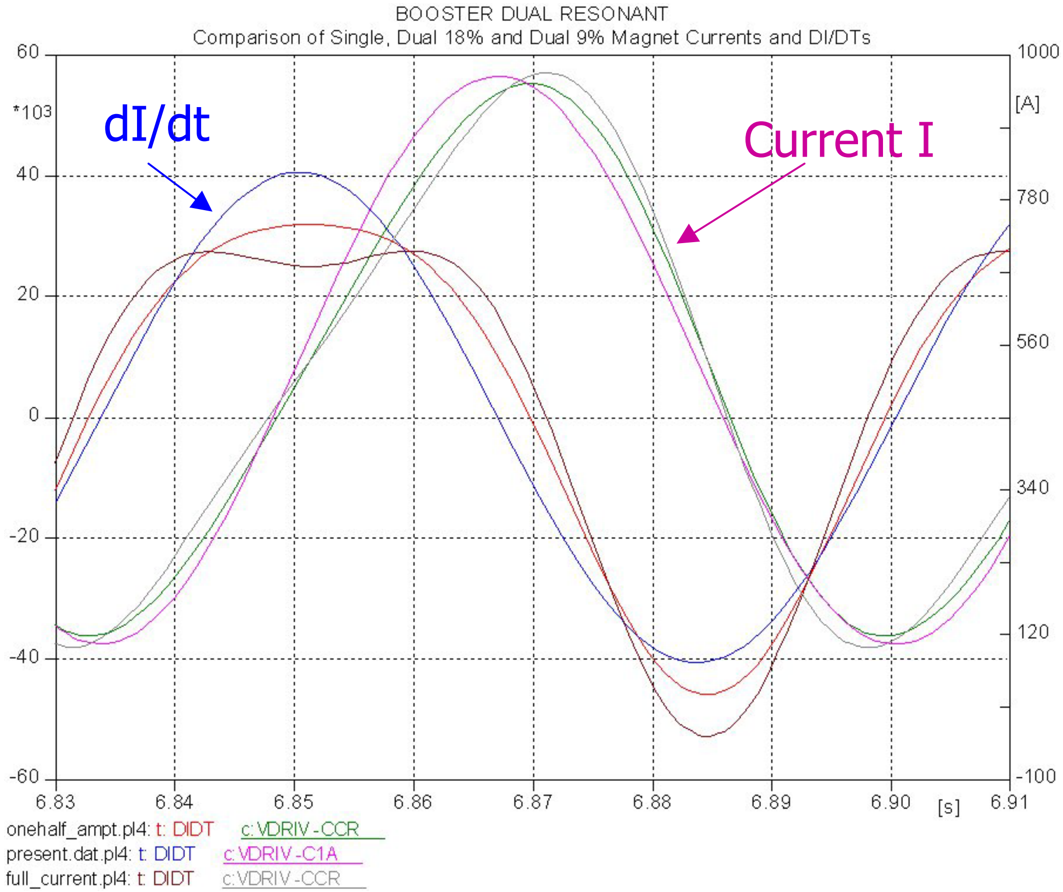


Dual Harmonic Power Supply
(D. Wolff, D. Harding and F. Mills)



Dual Harmonic Current and dI/dt

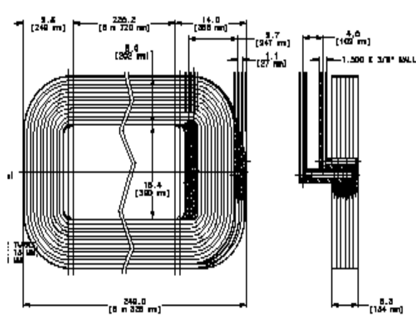
(3 cases: dual 0%, 9%, 18%)



Magnet R&D
(D. Harding)

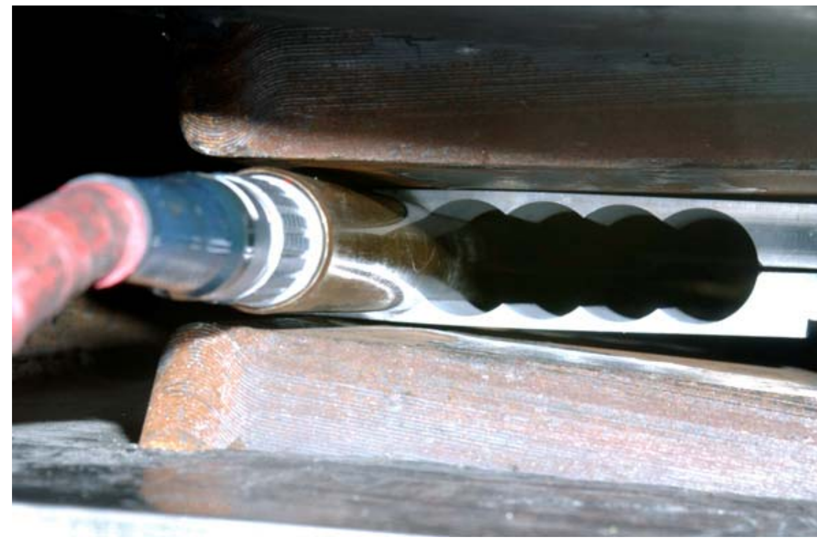
Stranded conductors

Standard conductors with parallel connection



- Insulation
  - Rad-hard
  - Low out-gassing
  - High voltage
- Conductors
  - Standard water-cooled
  - Stranded water-cooled
  - Transposed water-cooled
- Magnetic design
  - Refinements based on conductor, insulation, and other choices
- Magnetic measurement
  - Probes
  - DAQ

Field Measurement at E4R
(P. Schlabach and J. DiMarco)



A mole used for dc field measurement

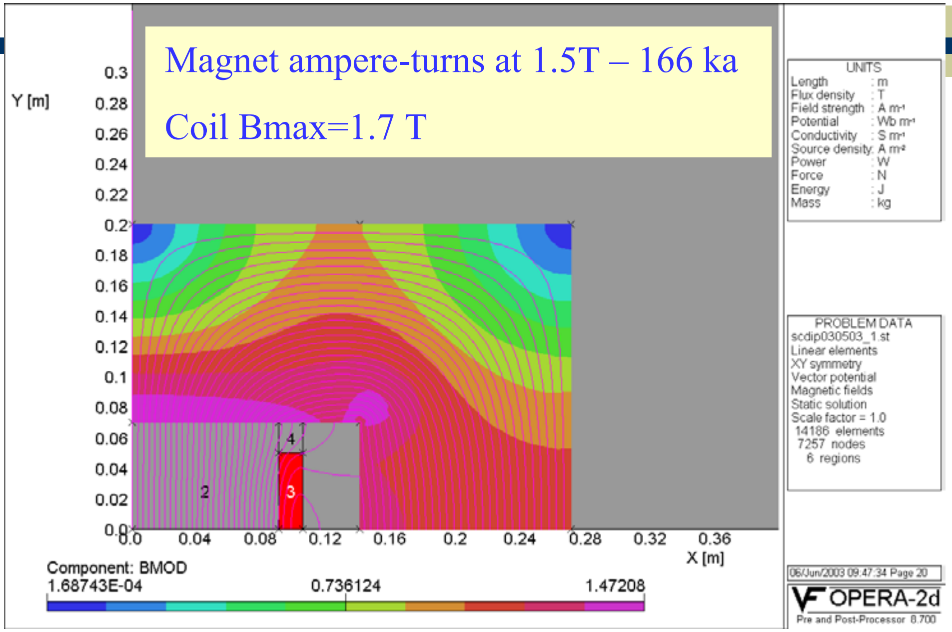
Superconducting Dipole Magnet

Main Issue:

Superconducting cable and winding with low eddy current losses

Magnet Parameters:

Magnetic field	**1.5 – 3.0 T**
Frequency	**15 Hz**
Air gap	**100 – 150 mm**
Length	**5.72m – 2.86 m**
Superconductor	**NbTi/CuNi or HTS**
Iron/air core	**room temperature**
Cooling	**LHe forced flow**



Superconductor AC losses < 3.3 kW/m^3 at 15 Hz and 0.5 mm dia.
Losses for 1.5 T magnet 1.2 W/m for NbTi/CuNi ALSTHOM superconductor with 0.16 um filaments

Hysteresis losses can be effectively reduced by decreasing a filament size up to ~ 0.2 um

Eddy current losses effectively reduced by using high resistive CuNi matrix and small twist pitch 1.5mm for sub-wire and 6-8mm in 0.5mm wire.

Careful optimization needed between SC cable, cooling pipes/channels and construction elements to reduce heat load up to reasonable value

AC Superconducting Magnet R&D
(V. Kashikhin)

Materials R&D:

- Investigate possible AC superconductor suppliers: ALSTHOM, FURUCAWA, HITACHI, SUMITOMO, OXFORD.
- Choose the conductor LTS vs. HTS and supplier.
- Purchase short length of conductor for cabling and tests.
- Test cable short samples.

01/01/04

Design & Analysis:

- Design the cable
- Magnetic design of short ~ 0.5 m length model
- Low AC losses elements design
- AC losses analysis
- Mechanical design and analysis
- Total heat load analysis and cooling design
- Final manufacturing drawings of short model.

03/01/04

AC Superconducting Magnet R&D (cont…)

External Project review:

- Final check possibility to achieve specified parameters
- Approval for magnet manufacturing

02/01/04

Manufacturing:

- Purchase parts
- Wind coils
- Manufacture cryostat
- Assemble cryostat with coils
- Assemble iron core
- Assemble iron core with cryostat

10/01/04

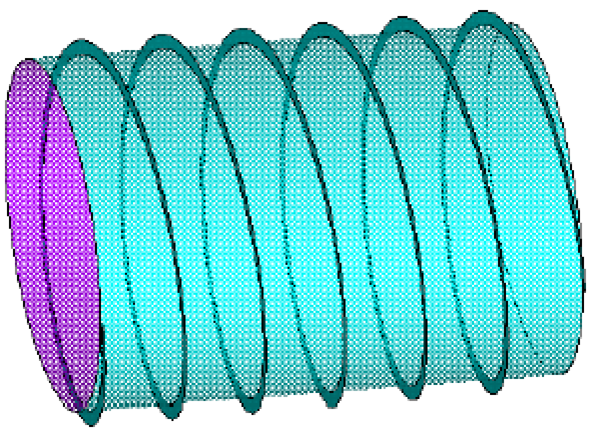
Tests:

- Purchase AC current leads
- Purchase AC power supply or main elements
- Assemble magnet test stand.
- Test the first model.

12/25/04

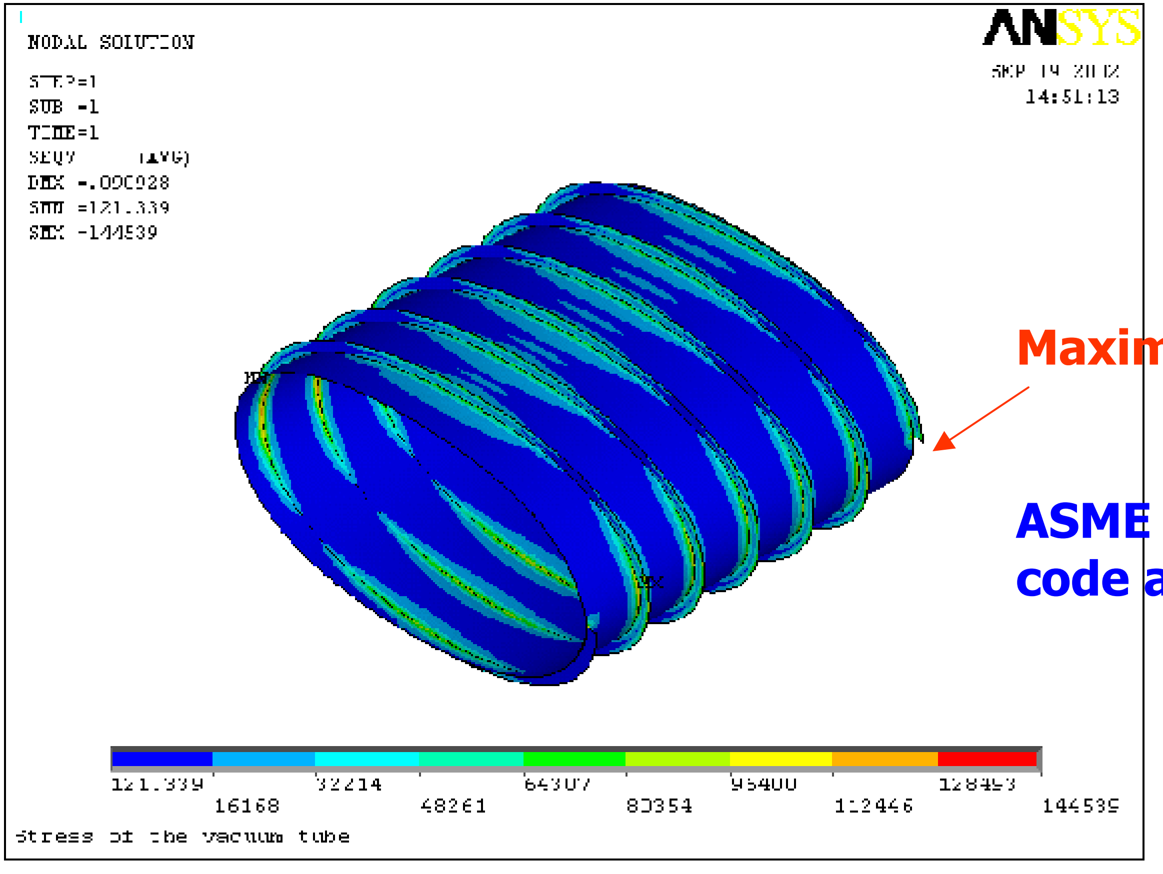
Thin Metallic Pipe Reinforced by Spiral Ribs

(Z-J. Tang, A. Chen and W. Chou)



- Aperture: oval shape, 4 in x 6 in
- Material: Inconel 718
- Wall thickness: 8 mils (0.2 mm)
- Spiral ribs: rectangular cross-section, width 28 mils, height 18 mils, 10 layers (total height 0.18 inch)
- Welding technique: laser deposition

Stress Analysis

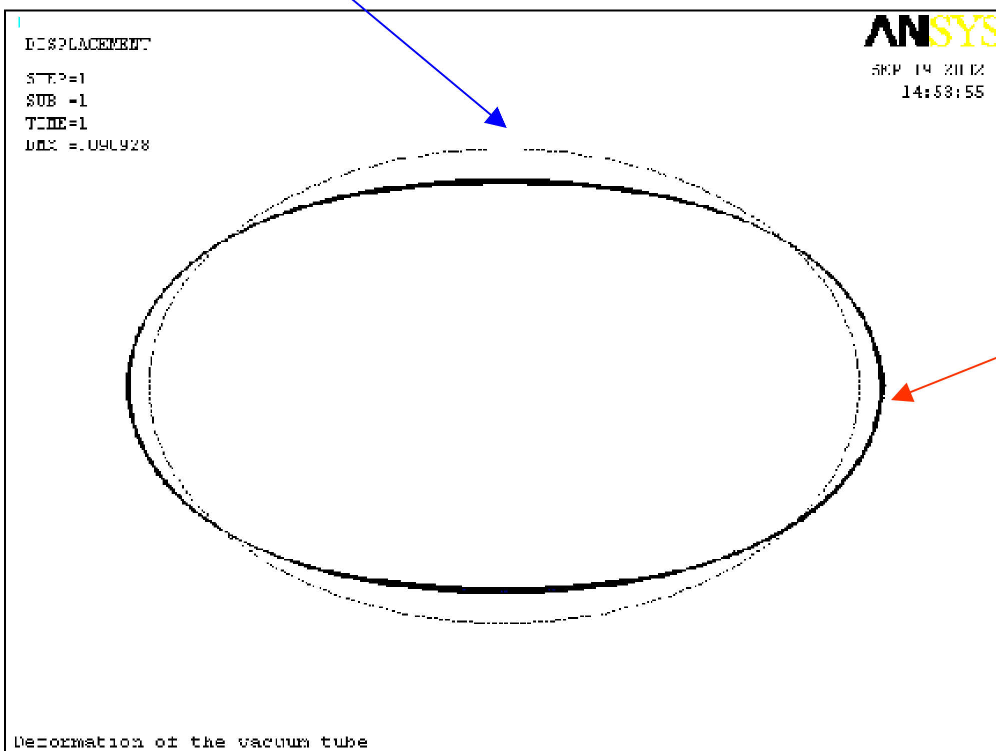


Maximum stress 130 ksi

ASME pressure vessel code allowance: 170 ksi

Deformation Analysis

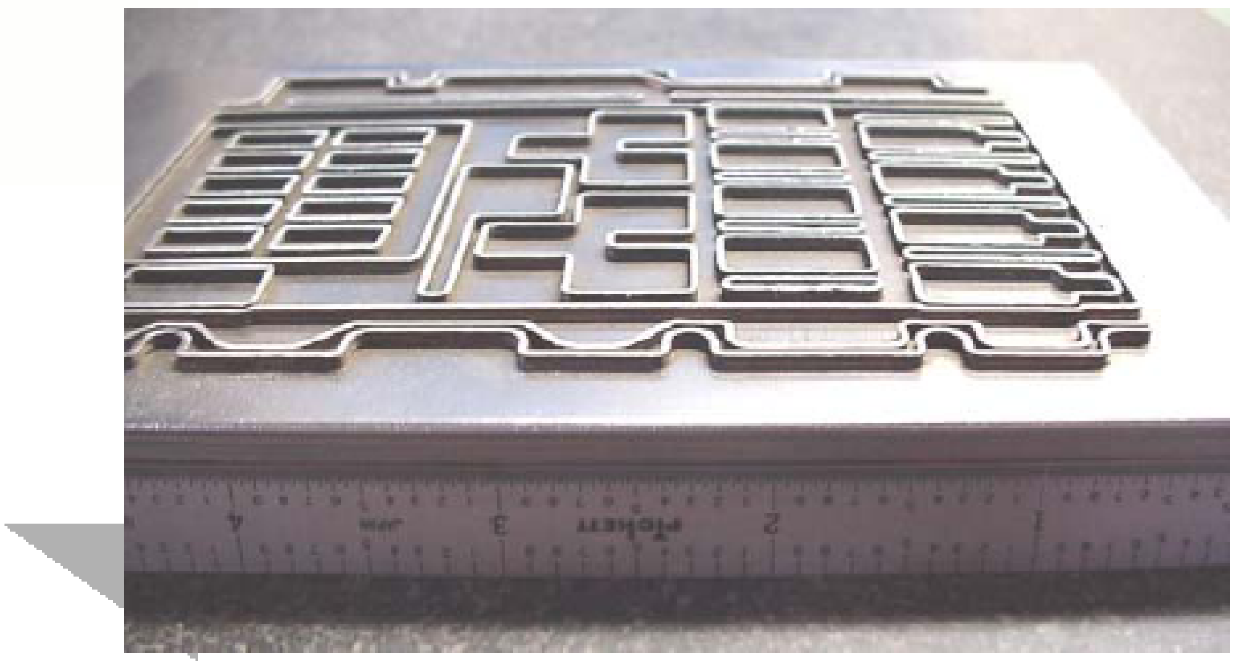
Max Δy = – 0.089 in



Max Δx = 0.055 in

Laser Precision Metal Deposition
(courtesy H&R Technology Inc.)

Cutting die prior to sharpening;
Die Base: Carbon Steel, Knife Pattern: 420 SST



Space Charge Study

- Code development
  - ESME (P. Lucas, J. MacLachlan)
  - ORBIT (F. Ostiguy, L. Michelotti, W. Chou)
  - Synergia (P. Spentzouris, J. Amundson)
- Work coupled with the Booster study

Inductive Inserts
(D. Wildman)

- Two modules have been tested, but inductance too low.
- To install more modules.

Collimation System
(A. Drozhdin and R. Alber)

- A critical system for meeting the requirement of 1 W/m of uncontrolled beam loss
- Rad-hot area, need specific mechanical and civil engineering design, e.g.,
  - fast disconnecting beam pipe modules
  - manipulators for remote connection and disconnection of collimators
  - removal and transportation of failed activated elements to the storage area
  - storage area design
  - monitoring of radiation conditions
  - Shielding

Booster RF Cavity Modification
(J. Reid and MiniBooNE team)

- To increase the aperture from 2-1/4 in. to 5 in.
- To increase the gap voltage from 55 kV to 66 kV.
- Two modified cavities will be installed during the summer shutdown.
- Work coupled with MiniBooNE project.

Linac Improvement Cost Estimate

◆ New 200 MHz front end & Tank 1 (10 MeV)	$4M
◆ New 402 MHz low energy section (116 MeV)	$27.6M (incl. $4M)
◆ New 805 MHz sc high energy section (313 – 500 MeV)	(TBD)

R&D Cost Estimate (M/S Part)

Laser chopping	$38 k
Dual harmonic power supply test	$45 k
Thin metallic pipe	$60 k
Inductive inserts	$ 6 k
Magnet R&D	$60 k
AC sc magnet development	$50 k
Collimation system	$10 k (FESS)
RF modification	$0
Total:	$269 k

Questions?